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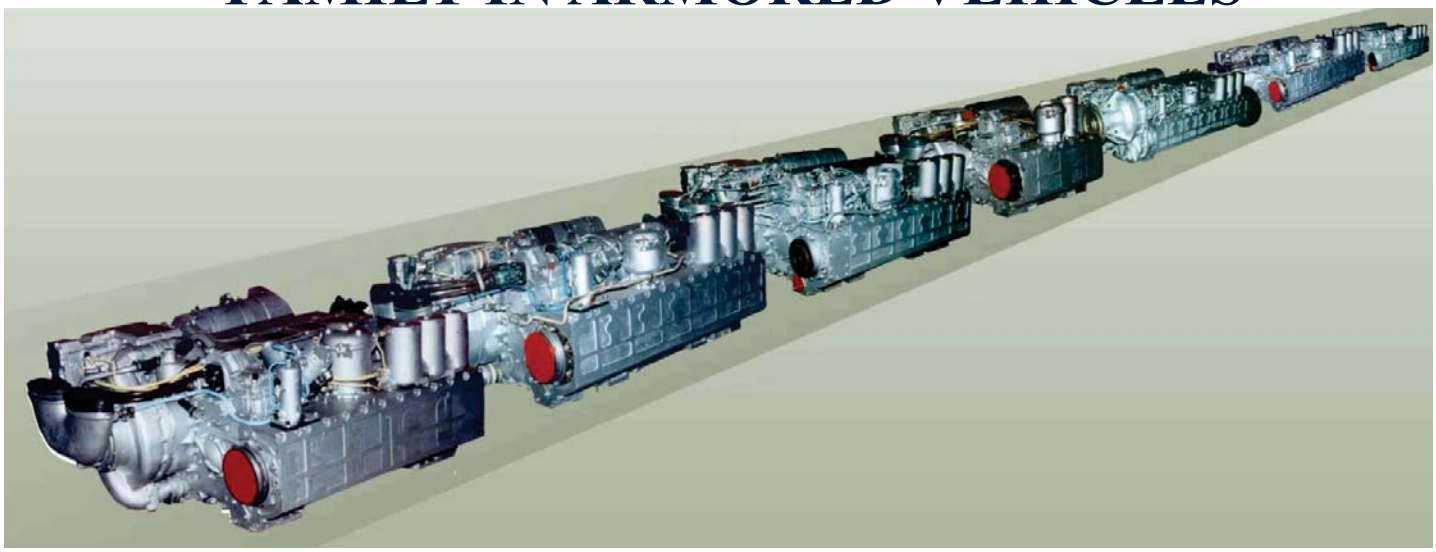
PROSPECTS OF APPLICATION OF TWO-STROKE TURBO-PISTON OPPOSED-PISTON DIESEL ENGINE OF TD FAMILY IN ARMORED VEHICLES



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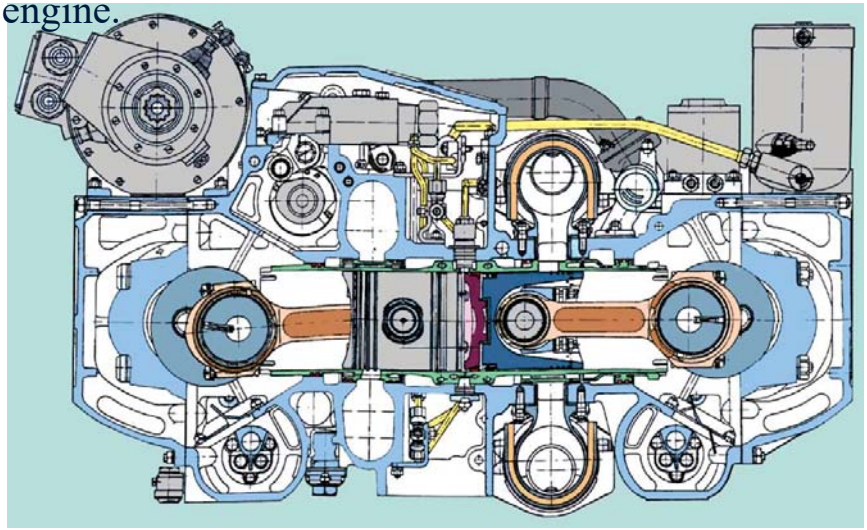
Main advantages of TD engines.

Engines of this family have following design characteristics, which ensure advantages over rival firms, which manufacture four-stroke engines:

1. Small overall dimensions in combination with high power.
2. Small heat emission to the cooling system and possibility to operate at high temperatures of liquid and motor oil cooling.
3. Small displacement and weight of power pack compartment of combat vehicle
4. High acceleration and brake power of the engine.
5. Good effectiveness.
6. Minor losses of engine power when operating at high ambient temperatures and in mountain.
7. High reliability and maintainability
8. Multi-fuel operation
9. Universal layout of engine
10. Reliable starting.



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1. Small overall dimensions in combination with high power.

Engine 6TD-2 – one of the representatives of TD family – has displacement 0.88m^3 and power 1200 hp, power-to-weight ratio makes 1363 hp/m^3

One of the best rival firm has following performances:

Russian engine V92S2 has displacement 1.18m^3 and develops power up to 1000 hp; power-to-weight ratio makes 847 hp/m^3, at that it should be taken into consideration that engine V92S2 does not include starter-generator and high-pressure air compressor and engine 6TD-2 does have them.

German engine MV873KA501 of "MTU" company has displacement 3.68 m^3 and develops power up to 1500 hp; power-to-weight ratio makes 407 hp/m^3.

As evident from the examples the power-to-weight ratio of engines of 6TD type is 1.6…3.3 times higher as compared to the competitors.

Smaller overall dimensions of 6TD engines determine smaller weight as compared to the other engines. Specific weight of 6TD-2 engine makes 0.98 kg hp, that is better than Russian engine V92S2 by 20% and than German engine MV873KA501– by 80%.

These high performances are achieved due to application of two-stroke cycle in diesel operation and higher speed of crankshaft (2800 min^{-1}). The letter gives possibility to transfer power from engine to the gearboxes without intermediate reduction gear, which increases weight, volume of engine compartment and power loss of power unit as a whole.

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2. Small heat emission to the cooling system and possibility to operate at high temperatures of liquid and motor oil cooling.

Total heat emission of two-stroke engine to the cooling liquid and oil makes 17…18% of heat entered the engine together with fuel (1.6 MJ/kWh). In four-stroke engines this figure makes 22…25% (2.1 MJ/kWh). Therefore if the power of engines is equal the application of engines of 6TD type ensures decrease of the required power of cooling system by more than 30% in comparison to the four-stroke ones that makes is possible to decrease the size of radiators and power consumption for fan drive of this system.

In case of upgrading of the existing models of armored vehicles when installing new engine of TD type having power by 30% higher than standard one the replacement of the existing cooling system is not required as the total heat emission of the engine will be the same.

Engines of TD type can operate at 130°C temperature of cooling liquid and oil. This gives the advantage when operating in desert.

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3. Small displacement and weight of power pack compartment of combat vehicle.

Power pack compartments occupy 30…40% of the total space of the armored vehicle. Weight and size of the combat vehicle substantially depend on the size of power pack compartment.

Internal space of tanks of Ukrainian manufacture does not exceed 11m^3, and size of PPC does not exceed 3.1m^3 with engine power of 1200 hp (T-84 tank). The internal space of tanks of European countries with four-stroke engine (France, England, Sweden, Germany) makes 17…18m^3, and PPC size is 6…7m^3. Note that engine occupies 30…35% and power unit cooling system occupies 30…40% of the PPC. Basing on advantages in comparison to the four-stroke engines namely smaller sizes of engine and cooling system PPC with engine of TD type leaving its competitors behind was developed.

Power-to-weight ratio of new tanks of the developed countries makes: England – 240 hp/m^3, Russia - 312 hp/m^3, Germany - 333 hp/m^3, Ukraine - 400 hp/m^3.

Basing on these figures the Ukrainian PPC is 1.2…1.6 times better than competitors' one.

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4. High acceleration and brake power of the engine.

Engines of TD type are equipped with compressor of supercharging air and power turbine, which have direct rigid (gear) connection with engine crankshaft.

This structure ensures high accelerating characteristics of combat vehicle.

When engine braking the tank produces brake power, which makes 50% of the rated effective power. In four-stroke engines this figure makes not more than 20…25%. High acceleration and brake power of the engine ensure advantages when operating the combat vehicle.

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5. Good effectiveness.

The indicated efficiency of TD-type engines is 50%, the effective efficiency is 40%, the fuel rate is 155…165 g/hp.h, which corresponds to the best two-stroke and four-stroke diesel engines. Taking into account that the power loss in the power pack compartment fitted with the engines of TD type are less owing to non-availability of losses in the intermediate reduction gear, decrease of power consumption for cooling system fan drive, the operational effectiveness of these engines is better than of four-stroke engines.

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6. Minor losses of engine power when operating at high ambient temperatures and in mountain.

The power losses of engines of TD type are 1.8…2.2 times less than those of four-stroke engines when operating at +55ºC. This advantage is achieved due to the high effectiveness of turbo-supercharging aggregates, high level of air charge turbulization in the combustion chamber, intensive system of carburation and combustion.

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7. High reliability and maintainability

In the TD-type engines the gas exchange process is performed by way of direct-flow movement of air and gas in the engine cylinder at the expense of pressure difference in the inlet and outlet receivers. There is no gas-distributing valve gear typical for the four-stroke engines in the TD-type engines. Besides, in TD type engine the combustion chamber is formed directly between two moving pistons, this eliminates availability of the cylinder head and the gas joint in this place. According to the statistical data 40…50% failures in the four-stroke engine operation are caused by damages of gas-distributing valve gear and seal failure of gas joint between the cylinder head and engine block.

The most frequent damages of valves and seal failure of gas joint happen at high ambient temperature, it requires the additional routine maintenance and repair during four-stroke diesel engine operation.

During operation of TD-type engines the fulfillment of above-mentioned scope of works is not required.

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8. Multi-fuel operation

The TD-type engines make it possible to use jet fuel (kerosene) and petrol along with diesel fuel.

This requirement is met at the expense of availability of the heat plate in the pistons, which reaches the temperature up to 1000ºC and ensuring the high effectiveness of the fuel combustion with the nozzles arranged in the combustion chamber at the equal distances.

Because of the outlet valves in the four-stroke diesel engines the meeting of this requirement is made with some restrictions.

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9. Universal layout of engine

All versions of TD-type engines enable power take-off from two sides of crankshaft plus additional power take-off for the cooling system fan drive or other needs. The overall dimensions of engine are small: the height of engine is 580mm, the width is 950 mm, which enables a big variety of versions of its installation into power pack compartments of various armoured vehicles.

The engine includes the starter-generator of 5, 10, 18 kW and high-pressure compressor of 150atm, which are not available in a lot of four-stroke engines.

As a rule the engine is installed on three supports (two supports in the clips and one floating support), it does not require the procedure of the common centering with the reduction gear and gear boxes as it is required for four-stroke engines.

The TD-type engines can be connected with the power-consuming units through tooth-type coupling, coupling with rubber-bushed studs, torus type coupling or using the engagement. Engine can operate with cooling systems of ejector and fan types with rarefaction at the suction up to 0.015MPa and counter-pressure at the outlet up to 0.034 MPa.

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10. Reliable starting.

The engines are equipped with pneumatic, electric and combined starting systems.

Starting facilitation systems are available: autonomous torch heater and calorizer starting system.

The engine is surely started over the temperature range from minus 40^0C to plus 55^0C.

It can be started using the tow and using the auxiliary power source (APU).

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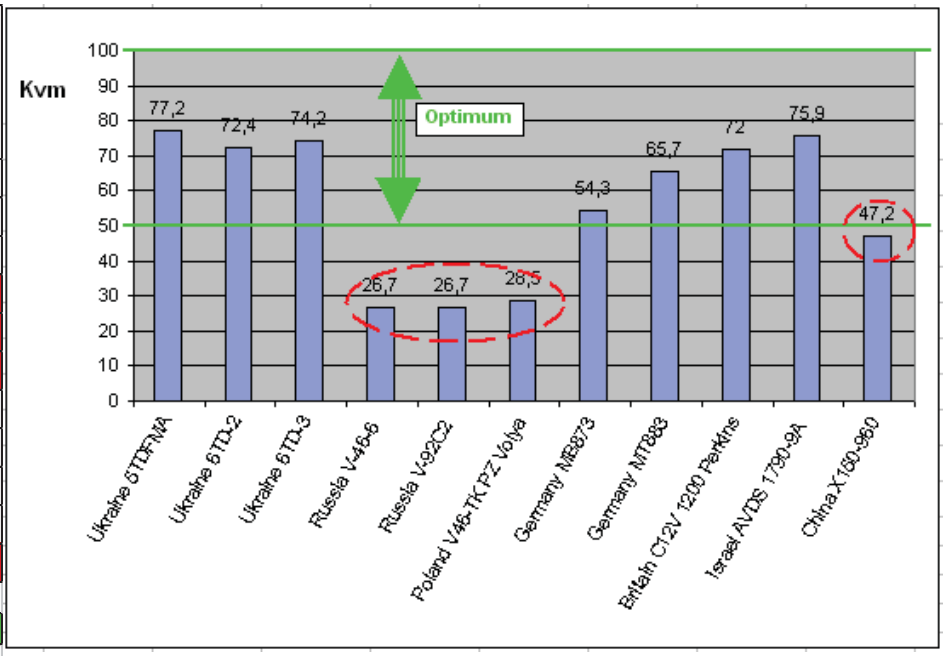
RELIABILITY AND LIFE OF TANK DIESEL ENGINES
CRITERIA COMPARATIVE TABLE
Volume mass coefficient

Country & Engine	Power, HP	Mass, kg	Op. volume, l	Volume mass coeff-t Kvm
Ukraine 5TDFMA	1050	1050	13,6	77,2
Ukraine 6TD-2	1200	1180	16,3	72,4
Ukraine 6TD-3	1400	1210	16,3	74,2
Russia V-46-6	780	1020	38,2	26,7
Russia V-92C2	1000	1020	38,2	26,7
Poland V46-TK PZ Volya	1000	1020	38,2	28,5
Germany MB873	1500	1090	38,2	54,3
Germany MT883	1500	2590	47,7	65,7
Britain C12V 1200 Perkins	1200	1800	27,4	72
Israel AVDS 1790-9A	1200	1880	26,1	75,9
China X150-960	960	2223	29,3	47,2
			Better	50...100 *
* Kosjak A.F., Bernadiner A.G., Cavushkin V.P.				
Снижение металлоемкости дизелей. - Труды ЦНИИДИ, 1981, p.13-21				



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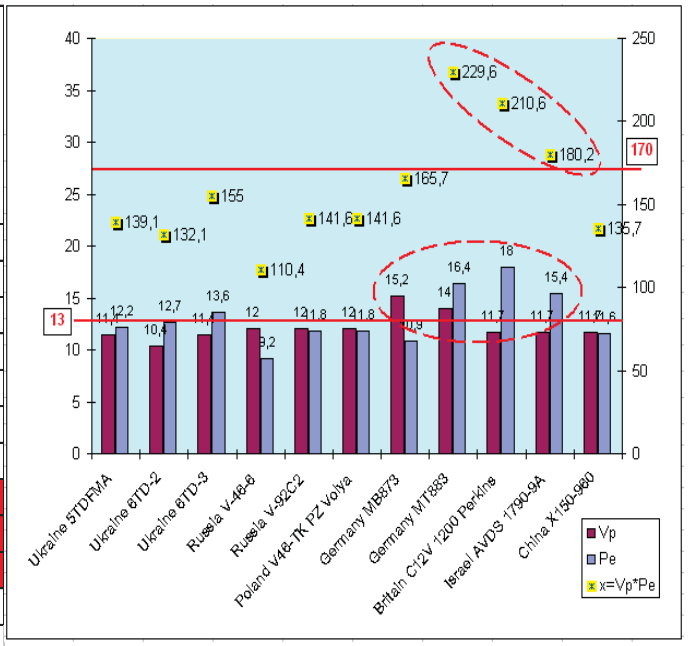
RELIABILITY AND LIFE OF TANK DIESEL ENGINES
CRITERIA COMPARATIVE TABLE
Average Piston Speed, Average effective pressure and Life criteria

Country & Engine	Power, HP	Rot. freq., r/min	Size D/L, mm	Op. volume, l	Av. Piston Speed Vp, m/s	Av. effect-tive pres-sure Pe, bar	Life crite-ria, x=Vp* Pe
Ukraine 5TDFMA	1050	2850	120/ 2x120	13,6	11,4	12,2	139,1
Ukraine 6TD-2	1200	2600	120/ 2x120	16,3	10,4	12,7	132,1
Ukraine 6TD-3	1400	2850	120/ 2x120	16,3	11,4	13,6	155
Russia V-46-6	780	2000	150/180	38,2	12	9,2	110,4
Russia V-92C2	1000	2000	150/180	38,2	12	11,8	141,6
Poland V46-TK PZ Volya	1000	2000	150/180	38,2	12	11,8	141,6
Germany MB873	1500	2600	170/175	38,2	15,2	10,9	165,7
Germany MT883	1500	3000	144/140	47,7	14	16,4	229,6
Britain C12V 1200 Perkins	1200	2300	135/152	27,4	11,7	18	210,6
Israel AVDS 1790-9A	1200	2400	146/146	26,1	11,7	15,4	180,2
China X150-960	960	2200	150/160	29,3	11,7	11,6	135,7
				Better	<13	<14	<170



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RELIABILITY AND LIFE OF TANK DIESEL ENGINES
CRITERIA COMPARATIVE TABLE
Heat emission, Volume and Mass of Power Pack

Country & Engine	Tank	Power, HP	Rot. freq., r/min	Size D/L, mm	Op. volume, l	Q, taus.kcal/hr	d Q	PP Volume, kub.m	PP mass, kg	Nv, hp/kub. m	d	Mn, kg/hp	d
Ukraine 5TDFMA	T-72 Upg	1050	2850	120/ 2x120	13,6	285	2%	3,0	2900	350	-10%	2,8	10%
Ukraine 6TD-2	Oplot	1200	2600	120/ 2x120	16,3	340	21%	3,1	3000	387	Base	2,5	Base
Ukraine 6TD-3		1400	2850	120/ 2x120	16,3	410	46%	3,2	3100	438	13%	2,2	-11%
Russia V-46-6	T-72	780	2000	150/180	38,2	280	Base	3,2	3200	244	-37%	4,1	64%
Russia V-92C2	T-90	1000	2000	150/180	38,2	365	30%	3,2	3300	313	-19%	3,3	32%
Poland V46-TK PZ Volya	PT-91	1000	2000	150/180	38,2	420	50%	3,2	3400	313	-19%	3,4	36%
Germany MB873	Leopard-2	1500	2600	170/175	38,2	580	107%	7,2	6150	208	-46%	4,1	64%
Germany MT883	Leopard-2	1500	3000	144/140	47,7	520	86%	4,3	5440	349	-10%	3,6	45%
Britain C12V 1200 Perkins	Challenger-2	1200	2300	135/152	27,4	445	59%	5,0	4400	240	-38%	3,7	47%
Israel AVDS 1790-9A	Merkava-3	1200	2400	146/146	26,1	425	52%	7,5	6500	160	-59%	5,4	117%
China X150-960	Type 80	960	2200	150/160	29,3	350	25%	3,2	3300	300	-23%	3,4	38%

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RELIABILITY AND LIFE OF LIGHT ARMOURED VEHICLES DIESEL ENGINES CRITERIA COMPARATIVE TABLE

Country	Engine type	Power, HP	Rotation Frequency, r/min	Piston Diameter, mm	Piston stoke, mm	Operation volume, liter	Mass, kg	Kvm, kg/l	Av. Piston Speed V_p, m/s	Pe, Bar	Life crite-ria, $x=V_p*P_e$	Veng, kub. m	d Veng	Nv eng, hp/kub. m	Q, t.kkal/h	d Ne cool
Россия	УТД-20	300	2600	150	150	15,9	665	41,8	13	6,5	84,9	0,73	Base	412,2	108,0	Base
Россия	УТД-29	500	2600	150	150	26,5	850	32,1	13	6,5	84,9	0,77	6%	651,1	180,0	67%
США	VTA-903T	600	2600	140	121	14,8	1035	69,9	10,46	14,0	146,8	1,49	105%	401,4	213,3	98%
США	6V53T	264	2800	98,5	114,3	5,22	750	143,7	10,67	8,1	86,7	0,80	10%	329,0	93,9	-13%
ФРГ	MB-883-EaSa	600	2200	165	175	22,4	1250	55,8	12,8	11,0	140,3	1,41	94%	424,5	242,4	124%
Англия	CV8TCA	550	2300	135	152	17,4	1292	74,3	11,65	12,4	144,1	1,71	135%	321,3	222,2	106%
Франция	HS115-2	280	3000	110	108	8,2	625	76,2	10,8	10,2	110,6	0,81	11%	345,3	100,0	-7%
Украина	3ТД-2	400	2600	120	2x120	8,15	800	98,2	10,4	8,5	88,3	0,68	-6%	585,6	120,0	11%
							Better	50…100	<13	<14	<120					

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UNIFICATION OF ENGINES AND PROSPECT OF FURTHER DEVELOPMENT.

Engines of TD series have the same standard size (cylinder diameter - 120mm, piston stroke - 120 mm). Particular modifications are given below (The achieved level of power of each modification is not limited and can be increased by 20% depending on the requirements):

Engine name	Power, hp	Rated speed, min^{-1}	Qty of cylinders	Purpose
3TD-1	280	2800	3	BTR-70 BTR - 80
3TD-2	400	2600	3	BMP- 1 BMP- 2 BTR - 50
3TD-3	500	2600	3	BTR - 4
3TD-4	600	2600	3	BMP- 3
5TDF	700	2800	5	tank T- 64
5TDFM	850	2800	5	Tank BM "Bulat"
5TDFMA	1050	2850	5	Tank BM "Bulat-2" T-72, T-55
6TD-1	1000	2800	6	Tank T-80UD
6TD-2	1200	2600	6	Tank T-84, "Oplot"
6TD-3	1400	2850	6	

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The comparative analysis demonstrates the superiority of tanks equipped with the power pack compartment having two-stroke engines of TD family in available power, which determines the weight and dimension characteristics of the combat vehicle, mobility, dimension of silhouette to be hit.

CONCLUSION.

During development of the prospective models and upgrading of the available armoured vehicles it is reasonable to use two-stroke opposed-piston engines of TD-type as it ensures the overwhelming advantages in comparison with competitors

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